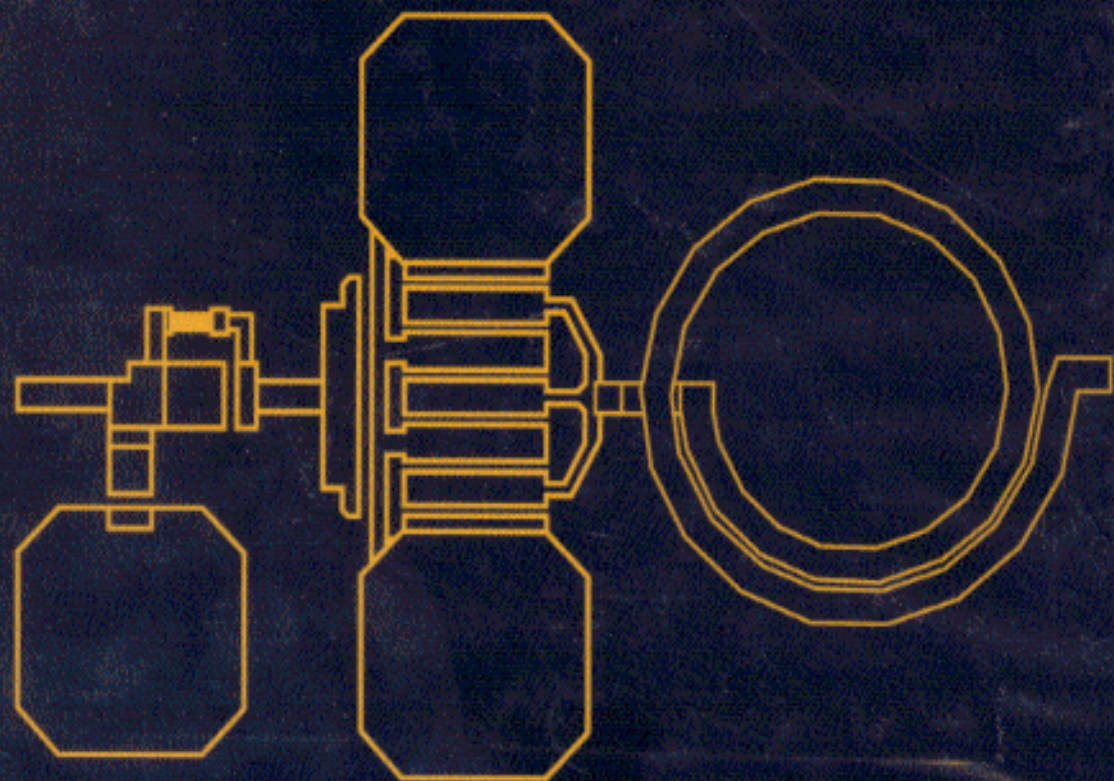


Microwave Solid State Circuit Design

Second Edition

Inder Bahl and Prakash Bhartia



CONTENTS

Preface	xiii
1 Introduction	1
<i>P. Pramanick and P. Bhartia</i>	
1.1 Characteristics of Microwaves/Millimeter Waves /	2
1.2 History of Microwave Planar Circuits /	4
1.3 Applications of Microwave Planar Circuits /	4
1.4 Microwave Network Theory /	6
References /	23
2 Transmission Lines and Lumped Elements	25
<i>Inder Bahl</i>	
2.1 Transmission Lines /	25
2.2 Coupled Lines /	46
2.3 Discontinuities /	52
2.4 Lumped Elements /	54
References /	72
Problems /	76
3 Resonators	79
<i>Arvind Sharma and A. P. S. Khanna</i>	
3.1 Introduction /	79
3.2 Resonator Parameters /	80
3.3 Cavity Resonators /	82

3.4 Planar Microstrip Resonant Structures / 90

3.5 Dielectric Resonators / 107

3.6 YIG Resonators / 119

3.7 Resonator Measurements / 123

References / 128

Problems / 130

4 Impedance Transformation Techniques 133

Prasad N. Shastry

4.1 Introduction / 133

4.2 Narrow-Band Transformation Techniques / 134

4.3 Wide-Band Transformation Techniques / 156

References / 177

Further Reading / 178

Problems / 178

5 Hybrids and Couplers 181

P. Bhartia and P. Pramanick

5.1 Introduction / 181

5.2 Design of Hybrids / 185

5.3 Coupled-Line Directional Couplers / 197

5.4 Design Considerations / 240

References / 243

Problems / 245

6 Filters 247

Edward Griffin and Inder Bahl

6.1 Introduction / 247

6.2 Filter Measurements / 255

6.3 Filter Synthesis / 256

6.4 Experimental Method of Designing Filters / 273

6.5 Filter Modeling / 278

6.6	Electromagnetic Simulation /	284
6.7	Filter Realizations /	286
6.8	Practical Considerations /	301
6.9	Electrically Tuned Filters /	307
	References /	311
	Problems /	315

7 Active Devices **317**

Robert J. Trew

7.1	Introduction /	317
7.2	Basic Semiconductor Device Equations /	317
7.3	Material Parameters /	320
7.4	Bipolar Transistors /	323
7.5	Field Effect Transistors /	342
7.6	HEMTs /	372
7.7	Comparison of Bipolar Transistor and FET Noise Figures /	377
	References /	377
	Problems /	380

8 Passive Devices **385**

Robert J. Trew

8.1	Introduction /	385
8.2	<i>pn</i> Junctions /	386
8.3	Schottky Barrier Junctions /	397
8.4	Varactor Diodes /	410
8.5	Varistors /	416
8.6	<i>pin</i> Diodes /	418
8.7	Step Recovery Diodes /	424
	References /	429
	Problems /	430

9	Oscillators	435
	<i>A. P. S. Khanna</i>	
9.1	Introduction /	435
9.2	Active Devices for Microwave Oscillators /	436
9.3	Concept of Negative Resistance /	438
9.4	Three-Port <i>S</i> -Parameter Characterization of Transistors /	438
9.5	Oscillation and Stability Conditions /	442
9.6	Transistor Oscillator Types and Configurations /	446
9.7	Fixed-Frequency Oscillators /	447
9.8	Wide-Band Tunable Oscillators /	467
9.9	Oscillator Characterization and Measurements /	478
	References /	490
	Problems /	492
10	Amplifiers	495
	<i>Inder Bahl and Edward Griffin</i>	
10.1	Introduction /	495
10.2	Amplifier Characterization /	496
10.3	Biasing Networks /	510
10.4	Small-Signal Amplifier Design /	511
10.5	Power Amplifiers /	523
	References /	552
	Problems /	555
11	Detectors and Mixers	559
	<i>Robert G. Harrison</i>	
11.1	Introduction /	559
11.2	Detectors /	567
11.3	Mixers /	583
	References /	620
	Problems /	625

12	Microwave Control Circuits	629
	<i>K. C. Gupta</i>	
12.1	<i>pin</i> Diode and MESFET Modeling for Control Circuits /	629
12.2	Design of Switches /	632
12.3	Design of Phase Shifters /	652
12.4	Design of Limiter Circuits /	676
12.5	Design of Variable Attenuators /	683
	References /	687
	Problems /	689
13	Frequency Multipliers and Dividers	693
	<i>Robert G. Harrison</i>	
13.1	Introduction /	693
13.2	Frequency Multiplication /	700
13.3	Frequency Division /	740
	References /	761
	Problems /	768
14	RF MEMS Devices and Circuit Applications	771
	<i>Ramesh Ramadoss and K. C. Gupta</i>	
14.1	Introduction /	771
14.2	RF MEMS Fabrication and Assembly /	772
14.3	RF MEMS Actuators /	778
14.4	RF MEMS Devices /	789
14.5	RF MEMS Circuit Applications /	813
	Appendix: Parameters of a Symmetrical T-Network /	841
	References /	843
	Problems /	847

15	Circuit Fabrication Technologies	851
	<i>Inder Bahl</i>	
15.1	Introduction / 851	
15.2	Printed-Circuit Boards / 858	
15.3	Microwave Printed Circuits / 860	
15.4	Hybrid Integrated Circuits / 865	
15.5	Monolithic Integrated Circuits / 873	
15.6	Technology Comparison and Choices / 876	
	References / 883	
Appendix A	Units and Symbols	887
Appendix B	Physical Constants and Other Data	891
Appendix C	<i>ABCD</i> and <i>S</i>-Parameters	893
Appendix D	Transfer Function Responses	899
Index		901